0.1 Project Background

In recent years, Deep Learning (DL) has significantly improved the performance of a wide range of computer vision tasks like image classification, object detection or semantic segmentation. Generative Adversarial Networks (GANs) in particular have revolutionized generative tasks like image synthesis and image-to-image translation. Image-to-image translation is the task of generating an image based on a given source image with different characteristics depending on the specific problem.

In this work, the idea of image-to-image translation is applied to the transformation of Confocal Microscopy (CM) histological images into Hematoxylin and Eosin stain (H&E) appearance.

0.1.1 Confocal microscopy

CM is an optical imaging technique for increasing optical resolution and contrast of a micrograph by means of using a spatial pinhole to block out-of-focus light in image formation. With it, technicians are able to slice thin sections out of thick fluorescent specimens, view specimens in planes tilted to the line of sight, penetrate deep into light-scattering tissues, obtain 3D views at very high resolution... (**Inoue2006**)

Ex vivo[1] confocal scanning laser microscopy can potentially accelerate Mohs surgery[2] by rapidly detecting carcinomas without conventional frozen histopathology (and its consequential time delays) (**Chung2005**).

Two different CM modes exist, Reflectance Confocal Microscopy (RCM) displays the backscattering signal of naturally occurring skin components, whereas Fluorescence Confocal Microscopy (FCM) provides contrast by using an applied fluorescent dye (**Skvara2012**).

0.2 Problem statement

CM has enabled rapid evaluation of tissue samples directly in the surgery room significantly reducing the time of complex surgical operations in skin cancer (**Cinotti2018**),

[1]Ex vivo means that which takes place outside an organism. In science, ex vivo refers to experimentation or measurements done in or on tissue from an organism in an external environment with minimal alteration of natural conditions.

[2]Mohs micrographic surgery is considered the most effective technique for treating many basal cell carcinomas (BCCs) and squamous cell carcinomas (SCCs), the two most common types of skin cancer. The procedure is done in stages, including lab work, while the patient waits. This allows the removal of all cancerous cells for the highest cure rate while sparing healthy tissue and leaving the smallest possible scar.

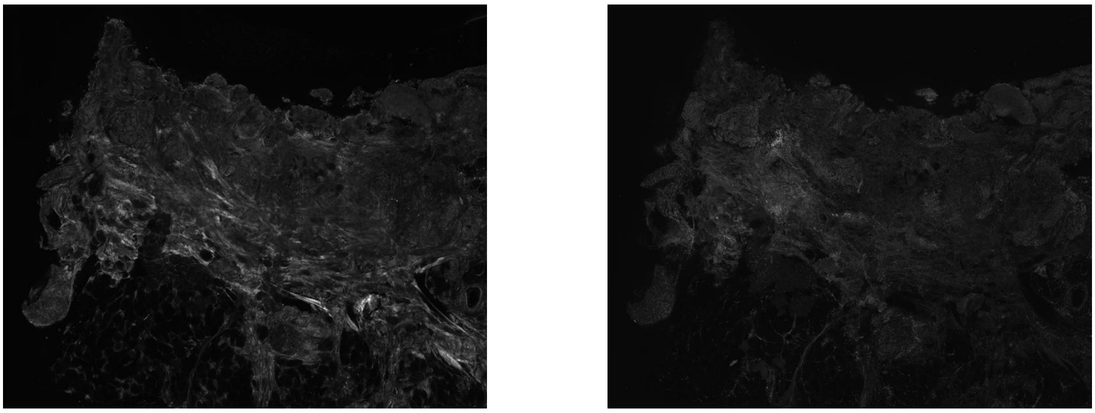


Figure 1: Example of a CM micrograph of a skin tissue. Reflectance mode on the left and fluorescence mode on the right

but the output largely differs from the standard H&E slides that pathologists typically use to analyze tissue samples.

To bridge this gap, a method for combining the aforementioned modes of CM into a H&E-like image is presented in this work. A correctly done CM to H&E mapping would bring the efficiency of CM to untrained pathologists and surgeons.

Similar to a false color (also known as pseudo color) transformation, a parametric mapping function can be defined:

$$\mathbf{DSCM} = f_\theta(\mathbf{R}, \mathbf{F}) \tag{1}$$

where $\mathbf{DSCM} \in \mathbb{R}^{3\times H\times W}$ (stands for digitally-stained CM) represents the resulting H&E-like RGB image, $\mathbf{R} \in \mathbb{R}^{H\times W}$ and $\mathbf{F} \in \mathbb{R}^{H\times W}$ represent the reflectance and fluorescence modes (respectively) of the CM input image with height H and width W.

0.2.1 Affine transformation

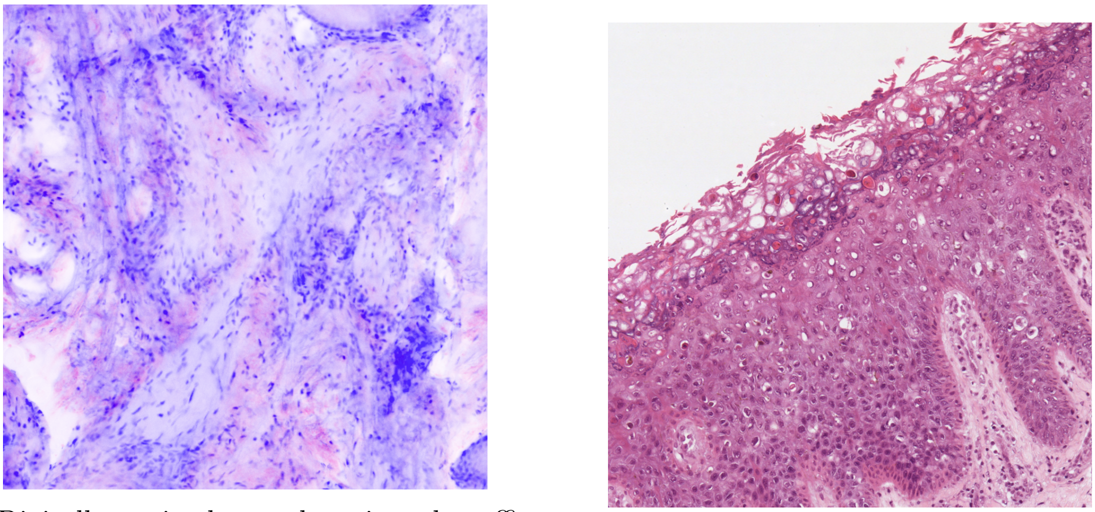
An affine transfomation is proposed in **Gareau2009** for the function f where each channel (c) is computed as:

$$\mathbf{DSCM}_{c,:} = \mathbf{1} - \mathbf{F}(1 - \mathrm{H}_c) - \mathbf{R}(1 - \mathrm{E}_c) \tag{2}$$

where:

$$\mathbf{H} = \begin{bmatrix} 0.30 & 0.20 & 1 \end{bmatrix}$$
$$\mathbf{E} = \begin{bmatrix} 1 & 0.55 & 0.88 \end{bmatrix}$$

These vectors represent coordinates in the RGB space (and). This way, the CM modes highlight different structures in distinct colours similar to a H&E slide; but as it can be seen in figure **??**, the color scheme differs from an actual H&E sample.



(a) Digitally stained sample using the affine transformation

(b) H&E stained sample

Figure 2: Comparison between digital stain and H&E stain

0.2.2 Data-driven approach

In contrast to **Gareau2009** work where the parameters (**H** and **E**) are found experimentally, a data-driven approach of the problem will be taken where the parameters of the mapping function (**??**) are *learned* based on data. More specifically, the transformation will be defined by a Neural Network (NN) (called *StainNN*) and the parameters will be searched through an adversarial setting.

0.2.3 Speckle noise reduction

RCM images are affected by a multiplicative noise known as speckle, which may impair the performance of post-processing techniques. Hence, before digitally staining the CM images, this noise must be reduced.

The observed RCM image Y is related to the noise free image X by the following multiplicative model:

$$Y = X \odot F \tag{3}$$

Where $\odot$ denotes the Hadamard product (also known as the elementwise product) and F is the speckle noise random variable.

To reduce the speckle noise, a data-driven approach will also be taken using the called *DespecklingNN*.

0.3 Methods and procedures

This project was carried out at the Image and Video Processing Group (GPI) research group from the Signal Theory and Communications Department (TSC) at the Universitat Politecnica de Catalunya (UPC) in collaboration with the Dermatology Department from the Hospital Clínic de Barcelona.

The work presented in this thesis is the natural continuation of the work presented in **Combalia2019**...

0.4 Document Structure

In section **??** an overview of relevant DL techniques and algorithms is presented to provide the reader a general knowledge of the field.

Section **??** contains the methodology of the project with detailed explanations of the models used to solve the presented problems. First the *DespeklingNN* is introduced in **??** then the *StainNN* in **??**.

The experiments carried out to choose the right models are presented in section **??**.

Finally, the conclusions and future work are discused in section **??**.